

## COMPARISON OF VARIOUS MECHANICAL PROPERTIES OF FSPed AND BARE AISI 4337 STEEL

HARMANDEEP SINGH<sup>1</sup> & SUPREET SINGH<sup>2</sup>

<sup>1</sup>Department of Automobile Engineering, Chandigarh University, Gharuan, Mohali, Punjab, India

<sup>2</sup>Department of Mechanical Engineering, Chandigarh University, Gharuan, Mohali, Punjab, India

### ABSTRACT

*Friction Stir Processing (FSP) of AISI 4337 steel was done with Tungsten carbide (wc) tool under two different rotational speeds 100rpm and 200rpm, with feed rate of 30 mm/min and plunge depth of 1 mm. Optical microscopy analysis was conducted and the grain size in the processed zone was found to be refined to 2  $\mu\text{m}$ , and 3  $\mu\text{m}$  respectively, in comparison to base steel (average grain size 50  $\mu\text{m}$ ). The grain size was found to be increasing with increase in revolving speeds. This may be increasing due to the temperature parameter to increase in strain rate while the recrystallization. The mechanical properties like micro hardness, tensile and bending were studied. After annealing process, the carbide particles was observed in original martensite phase. According to the increase in grain size. Good strength-ductility observed with YS of 650 Mpa and 970 Mpa. This is may be fact that increase in the grain boundaries decreases in the grain size. Friction stir processing also modified the properties of AISI 4337 steel microstructure.*

**KEYWORDS:** Friction Stir Processing, Microstructure, Mechanical Properties, Grain Refinement

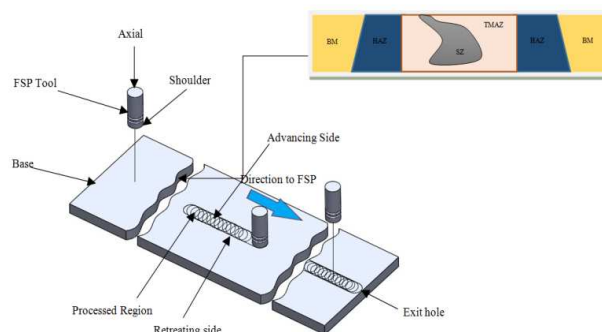
**Received:** Mar 17, 2018; **Accepted:** Apr 08, 2018; **Published:** Apr 24, 2018; **Paper Id.:** IJMPERDJUN20186

### INTRODUCTION

All things considered, the automotive industry having different experience sorts of surface dislikable like wear and corrosion. In oil hardware parts in Hydro turbine and gearbox. FSP is a method to change and microstructural control of surface thin layers of control steel parts for property improvement. It is powerful innovation for microstructure refinement, densification, and homogenization. FSP is a great way to deal with improving the refinement of the microstructure and mechanical properties of the material [1, 2]. In FSP the deserved parameter is used with the speed of rotational and longitudinal. It has been seen in the parameters that to handle the level of microstructure refinement of a grain. To control the calculated information and level of tensile in the material where the microstructure of the prepared material.

FSP is a new solid-state technique. In FSP as shown in figure.1 has four local the phases which are the district that is a thermo-mechanically prepared zone in which the grains measured is refined and homogenized. The thermo-mechanically affected zone (TMAZ) in which the grain is lengthened like it was mechanically distorted. The heat affected zone (HAZ) that as a same grain structure of the base material (BM) is the local that was unprocessed material. The unprocessed material incorporating the HAZ, its unique pre-prepared state i.e. parent material (PM) [3]. The examined on FSPed steels is as yet constrained because of the controlling and the founding stage change [4, 5]. In another side, the ultrafine grains changed their stage structure can be acquired in medium carbon steel by means of FSP and its great mechanical properties [6-7]. In the further examination on FSP of steels,

the development of microstructure is the impact on the FSP steel mechanical properties.



**Figure 1: Schematic of Friction Stir Processing Process**

In the current investigation on FSP of steels, the evolution of microstructure is the effect on the mechanical properties of the FSP steels. The obvious PZ is obtained with a depth of 1mm using without pin tool.

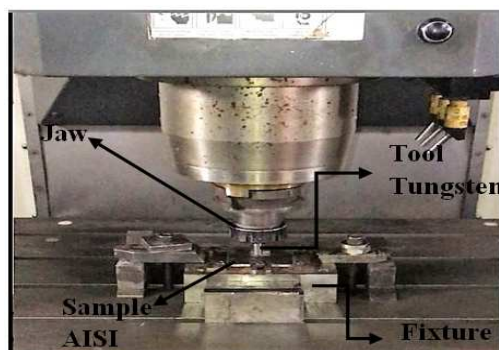
## EXPERIMENTAL PROCEDURE

### Friction Stir Processing

They chose steel AISI 4337 in the current work was gotten from Guru Nanak Dev Thermal Power Plant, Bathinda, Punjab (India). The Chemical Composition of AISI 4337 steel shows up in Table 1. The steel plates cutted into the dimension of 190mm x 50mm x 3mm. FSP technique was performed on tests by designed them in a uniquely composed device using VMC preparing machine. The Diameter of the tool is 10mm and the tool material is tungsten carbide (wc) .. The specially designed fixture was used to hold the workpiece on the VMC machine is EN31. The schematic illustration of the real FSP process is showing up in figure 2. FSP conveyed using pinless tool with plunge depth of 3mm, tool turning speed is 100rpm and 200rpm. The tests arranged at different speed were a task as FSPed-100 and FSPed-200. Subsequent to preparing the testicles test was rapidly cooled utilizing dry ice. The Chemical Composition of AISI 4337 steel is shown in table 1:

**Table 1: Chemical Composition AISI 4337 Steel**

Elements	C%	Mn%	Si%	P%	S%	Cr%	Mo%	Ni%	Fe%
Composition	0.38	0.68	0.30	0.035	0.04	0.82	0.22	1.67	95.76



**Figure 2: Schematic Illustrating of AISI 4337 Steel Sample with Fixture**

### Characterization of Substrate and FSPed Samples

The Friction Stir Processing (FSP) and base material (BM) tests were cross-sectional opposite to FSP course. Surface and cross-sectional microstructure of the base material and FSPed tests were analyzed by Optical microscopy (OM) (Leica, DFC 295, Japan). The Samples were cleaned by fabric while polishing to obtain the mirror finish. The samples are perfect and dried and the Nital solution (98% Ethanol + 2% nitric acid = Nital Solution) are applied on the a surface of sample to clearly shown grain estimate analyzed by microscope. Further, the surface analyzed of the FSPed tests was likewise examined with the assistance of Scanning electron microscope (SEM) (Joel 6610 LV).

The processed and unprocessed steel were complete using a smaller scale and Nano-space strategies. The microhardness was surveyed using a microhardness analyzer (Wilson, 402 MVD, Germany) at a load of 100g. The Nano-indent examination was coordinated using a Nano indenter (Hysitron, TI-900) at five unique zones at a load of 1000N using a standard Berkovich gem indenter. The hardness and Young's modulus of the illustrations were figured by Oliver–Pharr's technique.

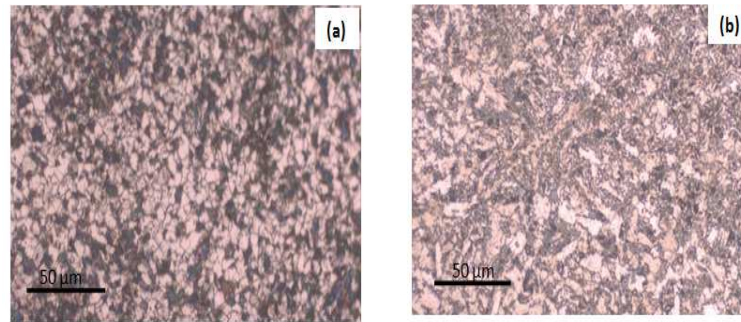
In mechanical property characterization, the Tensile are examination was completed at testing machines. The tensile test is done at (Tinius Olsen H50KS, Japan) machine. The measurement of tensile Samples is 32mm check length, 6mm check width, and 3mm measure thickness was in opposite PZ to the FSP course.

The bending test is done at (Tinius Olsen H50KS japan) machine. In bending testing a small indent cut in the example which is 3mm check thickness, 2mm measure length and 5mm check width at the FSP heading. Check the bending stress at the indent point and furthermore a similar procedure utilizing at BM test. The microhardness tests are performing on Wilson Instrument hardness analyzer utilizing 100g load for 10s.

## RESULTS AND DISCUSSIONS

### Microstructure

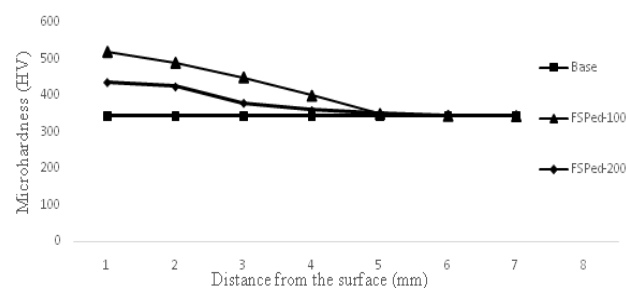
The optical magnifying instrument demonstrating the microstructure of the natural steel is given in figure 3 and the FSPed steel. In this figure the dark area is bainite and light area are ferrite. The grain estimate is expanding with an expansion in rotational rates. The base material grain measure is 50 $\mu$ m. This process was composed ferrite and bainite phases the cleaned and carved segments take from the FSP AISI 4337 plate that is demonstrating a huge variety amid grating mix preparing. Improved quality and malleability cooperative energy were acquired in the FSP medium carbon steel AISI 4337 subsequent to strengthening, because of the precipitation of the carbides in the martensite stage [19]. The OM showing the interface between the friction stir processed and unprocessed zone in which the transition in the microstructure could be observed clearly. The formation of dislocation and their arrangement along the grain boundaries during FSP such as microstructural changes also brought about a decrease in ductility of the steel due to decreasing in strain hardening capability coming from and increase the density during FSP. The Tool and shoulder mix with the material into the stir zone without changing the phases and create a modified microstructure having fine and mostly equal grains [21].



**Figure 3: Microstructure Map of (a) BM and (b) FSPed Steel**

### Microhardness

The separation between each indent is 0.5 microns. The BM contains a relatively low hardness value of 344 HV. In figure 4 showing the relationship between the BM and FSPed steel. The FSPed-100 steel hardness is 1.3 times increased then BM was 344 HV. The FSPed-100 and FSPed-200 hardness value is 520 HV and 437 HV respectively. The FSPed-100 and FSPed-200 are higher than the BM. The FSPed-200 in diminished as compared to the FSPed-100. The FSP demonstrates an impact on the microhardness of the steel to a profundity to the length of the device. The FSP demonstrates an effect on the microhardness of the steel to a significant to the length of the device. The development in the hardness of the steel may be cleared up in light of the Hall-Petch Equation [20]. Hall-Petch impacts more articulated on strengthening as the contrast with the strain hardening as a result of recrystallization while FSP. That disengagement density additionally enhances while doing FSP. The heap versus indents profundity plots for the handled and natural steel which acquired from the space examination. It plainly demonstrates the FSP steel is a high protection as the contrast with natural steel. Dependence of strain rate on grain size could be connected through more zener Holloman parameter, which demonstrates that an augmentation in strain rate is related to a comparing decrement in grain measure. Comparative outcomes have additionally been shown tentatively by Dehghani and Cha [21].



**Figure 4: Microhardness of the BM and FSPed AISI 4337 Steel with Distance from the Top Surface**

### Tensile

The typical engineering stress-strain curves of the BM and the annealed FSP samples, and the detailed tensile results are summarized in Table 2. In this table, unmistakably the annealed FSP tests still showed significantly higher than those of the BM. The yield stress and ultimate tensile strength of the FSPed-100 were 650MPa and 970 Mpa individually, which is significantly higher than the BM was 550 Mpa and 880 MPa. It's completely improved mechanical properties

with high strength. In the present work, the show desired strength can be accomplished by a basic annealing process at the different temperature. Besides, the FSPed-200 sample having 613 Mpa yield strength and 9235 Mpa ultimate tensile strength which is again higher than the BM. The EL tested on FSPed-100 is 19.05% which achieves the used EL in the greater part of the applications. The total elongation of FSPed-100 is 19.05% were the BM elongation is higher than the sample FSPed-100. The large processed depth and fundamentally enhanced mechanical properties in the PZ of the FSPed medium steel. Another side the FSPed-200 sample achieves 21.6% elongation which is higher than BM but diminished than the FSPed-100. This investigation gives a viable surface preparing strategy. This study provides an effective surface processing method. The yield strength of FSPed-200 in lower as compare to the FSPed-100. The ultimate tensile strength is also diminished as compare to FSPed-100. The stress-strain curves of the steel after and before FSP and the mechanical properties taken from the curves Figure 5. The steel before FSP consists low quality but good ductility. Compare with the BM, the tensile ductility plainly decreased in the FSP medium carbon steel, however, the high quality was expert. Other than the Carbide particles, numerous constant and discontinuous carbide strips could be found in the grains, which should to be credited to the precipitation of the carbides while the strengthening of the martensite [18]. This should relate to the improved quenching tendency in the steel due to the significant increase of the  $C_{eq}$ . It's results the formation of the quenching martensite structure in the PZ is easier. In addition, a couple of grains without the carbide existed in the tests, exhibiting that these grains ought to be the primary ferrite grains. It is notable that amid the stage change of the carbon steel, the martensite is transformed from the high-temperature austenite, which contains more carbon particles than the ferrite organize [22]. The cross-sectional micrograph of the FSP medium carbon steel test. The width of PZ was 10mm and for all intents and purposes identical to the shoulder distance across, credited to the effect of the shoulder. In addition, the profundity of the PZ was 1.5 mm, which is considerably greater than gotten by the SP or SMAT strategy [6, 9].

Hardness and tensile properties of the base material (BM) and FSP steel

Table

Samples	Hardness	YS (Mpa)	UTS (MPa)	EL (%)
BM	344	550	880	25
FSPed-100	520	650	970	19.05
FSPed -200	437	613	935	21.6

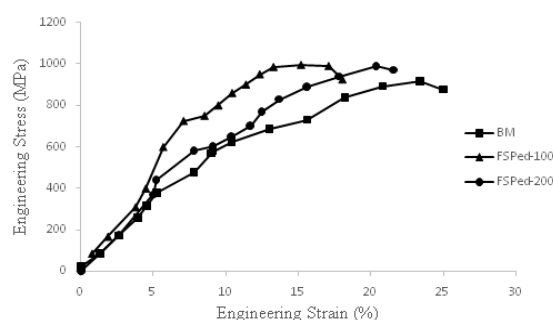
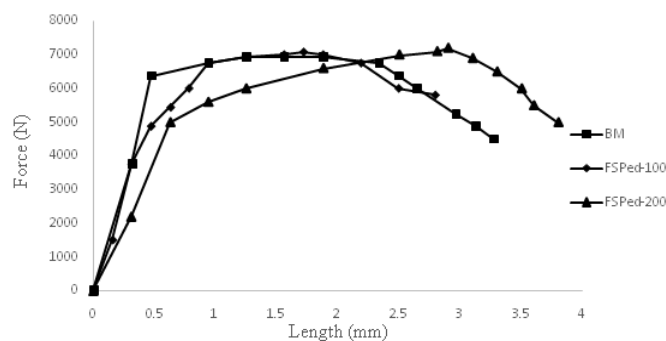


Figure 5: Engineering Stress-Strain Curves of BM and FSPed Steel

### Bending

This plot shows substantially more disseminate than showed up in that of as far as possible. The relation between the BM and FSPed steel in shown in Figure 6. The chart creates between Force (N) and Length (mm). The BM Yield

strength esteem is 7050 N and its length is 3.28mm. Contrast the BM and FSP-100 material in test FSPed sample the yield constraint is 7080N which higher than the BM and another side the length of test FSPed-100 sample is 2.8mm it diminishes than BM i.e. the BM is high twisting quality another side, the FSPed-200 having 6260 N yield strength which is diminished than the BM as well as FSPed-100. The length of the FSPed-200 is 4.5mm which is higher than the BM and FSPed-100. FSPed-100 has high return quality then different samples i.e. its break right on time than alternate samples. The handled surfaces were tried under elastic and pressure loads. Distinctive practices were watched for each twisting sample. The surface alteration by multi-pass FSP brought about an expansion of the most extreme load applied for all FSPed samples. FSP created a thin layer of a fine uniaxial recrystallized grain structure and homogeneous precipitation scattering and improving material quality[13]. When the martensite phase is changed with the rapid cooling stage. There the bending strength is high. Where the martensite phase no transform easily after rapid cooling than the bending strength is diminished [17].



**Figure 6: Bending Curves of BM and FSPed Steel**

## CONCLUSIONS

- Medium carbon steel was effectively grinding mix prepared at an instrument pivot rate of 100rpm and 200rpm for test FSPed with rapid cooling. Fundamentally upgraded hardness and the quality were accomplished in the PZ compared with the BM.
- Significantly enhanced hardness and the quality were accomplished in PZ contrasted with the BM. The hardness estimation of the FSPed-100 steel extended to 520 HV for FSPed-200 is the 437HV test which was considerably higher than the BM (344HV).
- After annealing carbide particles accelerated from the martensite stage and improved quality malleability cooperative energy was gotten in the FSP steel. High YS of FSPed-100 is 650Mpa and FSPed-200 is 613MPa were gotten in the FSPed steel compared with that of the BM(550MPa) yet the lengthening EL is lessened to 1.3times. The arrangement of fine grain size and better scattering of reinforcements. Since there is no pool of fluid dissolve all through the grains don't demonstrate the attributes sphericity. Additionally, studies about concentrating on the development of structure in the nugget zone may throw more light on the way in which the structure advances.



## ACKNOWLEDGEMENT

This work was supported by the Department of Automobile Engineering. The author would like to acknowledge the financial support of the University Institute of Engineering, Gharuan Chandigarh University.

## REFERENCES

1. Wheeler, D. W., and Wood, R. J. K 1999, "Erosion Wear Behaviour of Thick Chemical Vapour Deposited Diamond Coatings,"
2. Aldajah, S. H., Ajayi, O. O., Fenske, G. R., and David, S., 2009, "Effect of friction stir processing on the tribological Performance of High Carbon Steel,"
3. J. Sakamoto, Y. S. Lee, S. K. Cheong. *J. Mech. Sci. Technol.* 28(2014) 3555-3560.
4. Y. Harada, H. Kosaka, M. Ishihara, *Steel Res. Int.* 84 (2013) 1333-1339.
5. K. Lu, J. Lu, *Mater. Sci. Eng. A* 375 (2004) 38-45.
6. H. W. Huang, Z. B. Wang, J. Lu, *Acta Mater.* 87 (2015) 150-160.
7. R. S Mishra, Z. Y. Ma, *Mater. Sci. Eng. R50* (2005) 1-78.
8. M. Hajian, A. Abdollah- Zadeh. S. S. Rezaei-Nejad, H. Assadi, S. M. M. Hadavi, K. Chung, M. Shokouhimehr, *Appl. Surf. Sci.* 308 (2014) 184-192.
9. Y. Harada, H. Kosaka, M. Ishihara, *Steel Res. Int.* 84 (2013) 1333-1339.
10. AA5083-O and AA7022-T6 "Characterization and analysis of processed aluminum alloys".
11. Arora, H. S., Singh. H., and Dhindaw, B. K., 2013, "Wear Behaviour of an Mg alloy subjected to Friction stir Processing.
12. Chen, Y. C., and Nakata, K., 2009, "Evaluation of Microstructure and Mechanical properties in friction stir processing SKD61 tool steel.
13. Dodds, S., Jones, A. H., and Cater, S., 2013, "Tribological Enhancement of AISI 420 Martensitic Stainless steel Through Friction-Stir Processing.
14. Elangovan, K., and Balasubramanian, V., 2008, "Influences of tool Pin Profile and Tool Shoulder Diameter on the Formation of Friction Stir Processing Zone in AA6061 Aluminium alloy.
15. Shubhavardhan R N, Hybrid Microstructure and Tensile Strength of Friction Stir Welding of Al-Cu, *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)*, Volume 5, Issue 2, March - April 2013, pp. 41-50
16. Ghasemi- Kahrizsangi, A., and Kashani- Bozorg, S. F., 2012, "Microstructure and Mechanical Properties of Steel/TiC Nano-composite surface layer Produced by friction stir processing.
17. Mahmoud, T. S., 2008, "Effect of friction Stir Processing on Electrical Conductivity and corrosion Resistance
18. P. Xue, B. L. Xiao, W. G. Wang, Q. Zhang, D. Wang, QZ. Wang, Z. Y. Ma, *Mater. Sci. Eng. A* 575 (2013) 30-34.
19. H. K. D. H. Bhadeshia, T. DebRoy, *Sci. Technol. Weld. Join.* 14 (2009).
20. R. Rai, A. De, H. K. D. H. Bhadeshia, T. DebRoy, *Sci. Technol. Weld. Join.* 14 (2011) 325-342.

21. H. S. Grewal, H. S. Arora, H. Singh, S. Mukherjee (2012) "Improving Erosion Resistance of Hydroturbine steel using Friction Stir Processing.
22. K. Dehghani, A. Chabok, Dependence of Zener Parameter on the nanograins formed during friction stir processing of interstitial free steels, *Materials Science and Engineering A* 528 (2011) 4325-4330.
23. H. K. D. H. Bhadeshia, R. W. K. Honeycombe, *Steels Microstructure and Properties*, Third ed., Butterworth- Heinemann, Elsevier Ltd, Oxford, 2006